N 73 - 13290

NASA CONTRACTOR REPORT

NASA CR-112184

NASA CR-112184

CASE FILE COPY

DEVELOPMENT AND APPLICATIONS OF SUPERSONIC UNSTEADY CONSISTENT AERODYNAMICS FOR INTERFERING PARALLEL WINGS

USER'S MANUAL

by Andrew A. Paine

Prepared by

Bell Aerospace Company DIVISION OF textron

POST OFFICE BOX ONE

BUFFALO, NEW YORK 14240

for Langley Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • AUGUST 1972

N A S A   C O N T R A C T O R   N A S A   CR-112184

R E P O R T

NASA CR-112184

D E V E L O P M E N T   A N D   A P P L I C A T I O N S   O F   S U P E R S O N I C   U N S T E A D Y   C O N S I S T E N T   A E R O D Y N A M I C S   F O R   I N T E R F E R I N G   P A R A L L E L   W I N G S:

U S E R ' S   M A N U A L

By ANDREW A. PAINE

Prepared by

BELL AEROSPACE COMPANY
Post Office Box One
Buffalo, New York 14240

for Langley Research Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION · WASHINGTON D.C.

SUMMARY

This manual describes the input data required to execute the computer program AIC / INT, a nemonic derived from the problem title "DEVELOPMENT AND APPLICATION OF SUPERSONIC UNSTEADY CONSISTENT AERODYNAMICS FOR INTERFERING PARALLEL WINGS". (Bell Aerospace Report No. 2471-941001). A finite element analysis is employed.

The work was accomplished by Bell Aerospace Company under Contract NAS1-10880 with the National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia.

A sample case is included that shows both input and output.

TABLE OF CONTENTS

INTRODUCTION

This manual describes the input data required to execute the computer program AIC / INT (aerodynamic influence coefficients with interference). Applicability is aided by the theoretical overview (see Ref. 1) and a sample case, including output.

The purpose of the computer program is to generate aerodynamic forces for a pair of plane and interfering nearly parallel, non-coplanar wings at supersonic Mach numbers. A finite element technique has been employed. Planforms are described by triangular elements and diaphragm regions are generated automatically.

There are limitations to the program, in physical size (number of elements, grid points, etc.) and in analysis. The former is covered in this manual, the latter is found in Ref. 1. Of particular importance are the following

a. Wake calculations are not included (e.g. in a wing-horizontal tail combination the influence of the wake of the wing on the angle of attack of the horizontal stabilizer is ignored.)

b. Results for an isolated wing are generated when placement of the wings is such that no interference occurs. (i.e. place a one element wing directly above the main wing at large separation.)

SECTION 1

FORMULATION

The integral equations used for the computer program are presented here. A complete derivation of these equations will be found in Reference 1.

1. Velocity Potential - Interferring Case (Subprogram TRINTX)

The velocity potential influence coefficient matrix is given by:

$$\Phi_{ij} = -\frac{1}{\pi\beta}\int_{\xi_L}^{\xi_u} e^{-i\hat{k}\Delta x}\left[\Omega_u\Psi_u - \Omega_L\Psi_L - \Omega_n\int_{n_L}^{n_u}\Psi\, dn\right]d\xi \qquad (1.1)$$

The initial position of each element is assumed to be the average of its Z-coordinates. Integrands in Eq. (1.1) are analytic in the fore Mach cone region. A Gaussian type numerical integration with 5 pivotal points is employed in all cases.

2. Downwash Integrals (Subprogram DWASHY)

The downwash integral, after performing an integration by parts and simplifying, becomes (See Reference 1)

$$W_{ij} = -\frac{\beta\Delta z}{\pi}\left[I1_{ij} - I2_{ij}\right] \qquad (1.2)$$

where

$$I1_{ij} = \int_{\xi_L}^{\xi_u} e^{-i\hat{k}\Delta x}\left[\Omega_\xi\left(\Psi_L - \Psi_u\right) + \frac{1+i\hat{k}\Delta x}{\Delta x}\left(\Omega_L\Psi_L - \Omega_u\Psi_u\right)\right]d\xi \qquad (1.3)$$

and

$$I2_{ij} = \Omega_\eta\int_{\eta_L}^{\eta_u}\left[\left\{\frac{e^{-i\hat{k}\Delta x_u}}{\Delta x_u}\,{}_u\Psi - \frac{e^{-i\hat{k}\Delta x_L}}{\Delta x_L}\,{}_L\Psi\right\}\right.$$

$$\left. - \int_{\xi_L}^{\xi_u} \Psi\,\frac{e^{-ik\Delta x}}{\Delta x}\left(\frac{1+i\hat{k}\Delta x}{\Delta x}\right)d\xi\right]d\eta \qquad (1.4)$$

Since the singularities have been eliminated in these integrals, the limits of integration for the elements can extend up to the Mach cone. A typical element cut by the Mach cone is shown in Figure 1.1. Only partial integration is required here..
Numerical integration of the form

$$\int_{X_L}^{X_u}\int_{Y_L}^{Y_u} f(\xi,\eta)\, d\eta\, d\xi$$

is to be performed.

At a typical point, ξ_i the upper limit Y_u is redefined as Y_u' and the integration is stopped at the Mach cone. This technique is applied to all partial elements.

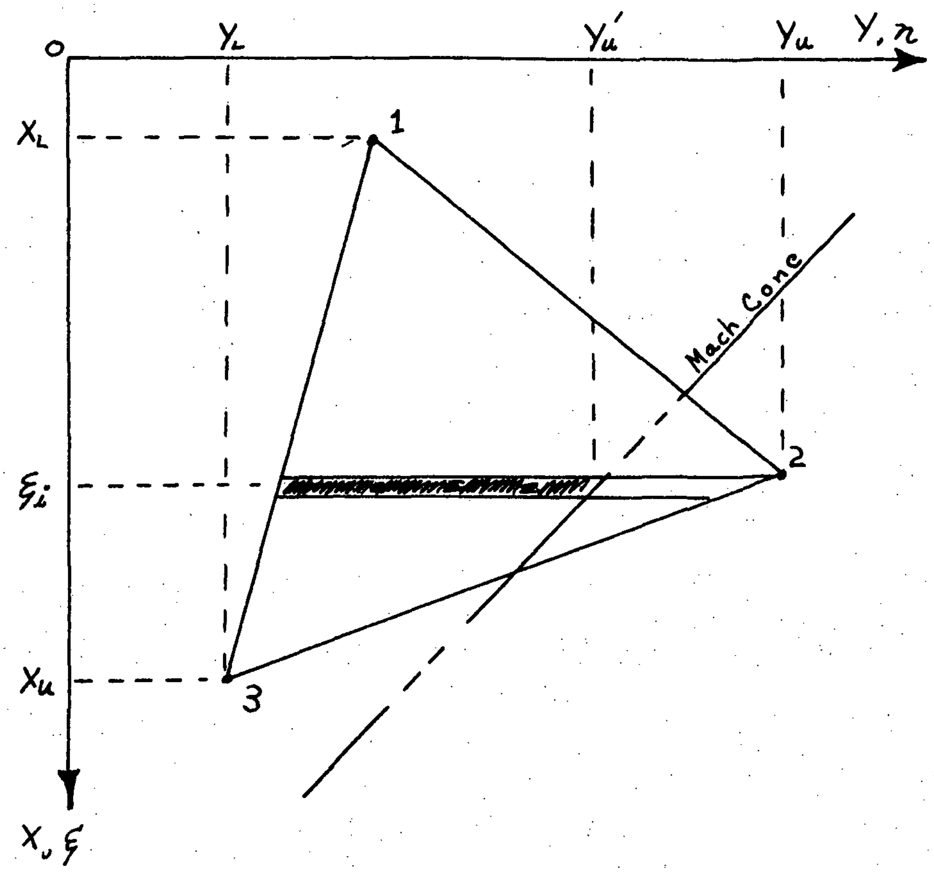


Figure 1.1 Partial Element Integration

3. <u>Source Strength</u> (Subprogram ASSDWN)

The relationship between source strength and input downwash is given by:

$$\begin{Bmatrix} \sigma_{1w}^{u} \\ \sigma_{2w}^{L} \end{Bmatrix} = \left[A^{-1} \right] \left[B \right] \tag{1.5}$$

$$[A] = \left[\begin{bmatrix} I_{11} & W_{12_W} \\ -W_{21W} & I_{22} \end{bmatrix} - \begin{bmatrix} 0 & -W_{12D} \\ W_{21D} & 0 \end{bmatrix} \left[\tilde{\Gamma} \right] \right] \tag{1.5.1}$$

$$[B] = \left[\left[I \right] + \begin{bmatrix} 0 & -W_{12D} \\ W_{21D} & 0 \end{bmatrix} \left[\tilde{\Gamma} \right] \right] \begin{Bmatrix} \frac{l}{U} \frac{D\tilde{Z}_1}{Dt} \\ -\frac{l}{U} \frac{D\tilde{Z}_1}{Dt} \end{Bmatrix} \tag{1.5.1}$$

The input downwash terms are given by:

$$\frac{l}{U} \frac{D\tilde{Z}}{Dt} = \bar{\lambda}\, q + \frac{\partial q}{\partial x} \tag{1.6}$$

where q is the displacement and $(\partial q / \partial x)$ the slope in the stream direction of each node point.

4. <u>Condensation of Velocity Potentials</u> (Subprogram ASSPOT)

$$\begin{Bmatrix} \Delta\phi_W \\ \Delta\phi_D \end{Bmatrix} = \begin{bmatrix} \Phi_{WW} & \Phi_{WD} \\ \Phi_{DW} & \Phi_{DD} \end{bmatrix} \begin{Bmatrix} \Delta\sigma^W \\ \Delta\sigma^D \end{Bmatrix} \tag{1.7}$$

where subscripts W and D denote the wing and diaphragm nodes.

From the condition

$$\Delta \tilde{\phi}_D = 0$$

the reduced potential becomes (1.8)

$$\tilde{\Phi}_{WW} = \left[\Phi_{WW} - \Phi_{WD} \cdot \Phi_{DD}^{-1} \cdot \Phi_{DW} \right] \tag{1.9}$$

$$\Delta \tilde{\phi}_W = \tilde{\Phi}_{WW} \cdot \Delta \sigma^W \tag{1.10}$$

5. Nodal Forces (Subprogram OUTPUT)

Nodal forces are determined from

$$P_i = -2 \rho V^2 \ell^2 \left[A_i \right] \left\{ \Delta \tilde{\phi}_i \right\} \tag{1.11}$$

where A is the assembled pressure matrix, and i = 1, 2 for wings 1 and 2.

6. <u>Generalized Forces</u> (Subprogram OUTPUT)

From the definitions in Reference 1,

$$Q_{\ell m} = -2\rho V^2 \ell^3 \tilde{Q}_{\ell m} \tag{1.12}$$

where

$$\tilde{Q}_{\ell m} = \left[X_\ell^T \cdot P_m \right] \tag{1.13}$$

X_ℓ = the ℓ th deformation mode

P_m = the nodal force distribution due to the deformation mode X_m

Ψ	=	$\Psi(\xi,\eta)$	Specific combinations of Bessel (integer order) functions
Ψ_L	=	$\Psi(\xi,\eta_L)$	
${}_L\Psi$	=	$\Psi(\xi_L,\eta)$	
Ω	=	$\Omega(\xi,\eta)$	Interpolation matrix: Cartesian to nondimensional coordinates.
Ω_L	=	$\Omega(\xi,\eta_L)$	
Ω_ξ	=	$\Omega(1,0)$	
Ω_η	=	$\Omega(0,1)$	
X_i	=	X coordinate, receiving element	
Y_i	=	Y coordinate, receiving element	
Z_i	=	Z coordinate, receiving element	
ξ	=	X coordinate, gaussian, influencing element	
η	=	Y coordinate, gaussian, influencing element	
ρ	=	Z coordinate, gaussian, influencing element	
ΔX	=	$X_i - \xi_j$	
ΔX_L	=	$X_i - \xi_L$	
ΔY	=	$Y_i - \eta_j$	
ΔZ	=	$Z_i - \rho$	
ω	=	angular frequency	
ℓ	=	reference length	
M_o	=	Mach number	
U	=	Flight speed	
β	=	$\sqrt{M_o^2-1}$	
$\hat{k}$	=	$\omega\,\ell\,M_o^2/U\beta^2$	
$\bar{\lambda}$	=	$\alpha\ell/U + i\omega\ell/U$	
Φ	=	velocity potential	

Table 1.1 Symbol Definitions

SECTION 2

INPUT OVERVIEW

The input package for this program expects to find required data arranged into specific groups. Each group of data, which may be one or more cards, is preceded by a LABEL card carrying an applicable name. These LABEL cards are used by the program as (1) an identifier for branching, and (2) a check that the data has been input. The input package supplied with this program will accept <u>only</u> the following LABEL data cards:

1. RUN
2. TITLE
3. SYSTEM
4. LEDGE
5. ELEM
6. COORD
7. MODE
8. END
9. ENDATA
10. FREQ

LABEL data sections are subject to the following rules:

Sections 1 and 2 are optional;
Sections 4, 5, 6, and 7 may appear in any order;
Section 3 <u>must</u> precede section 4, 5, 6, 7, 8;
Section 8 must be the last data card to describe a wing;
Section 9 must follow the second END card;
Section 10 must follow ENDATA.

Failure to observe these rules will terminate execution. Figure 2.1 gives an overview of physical arrangement of the total data deck.

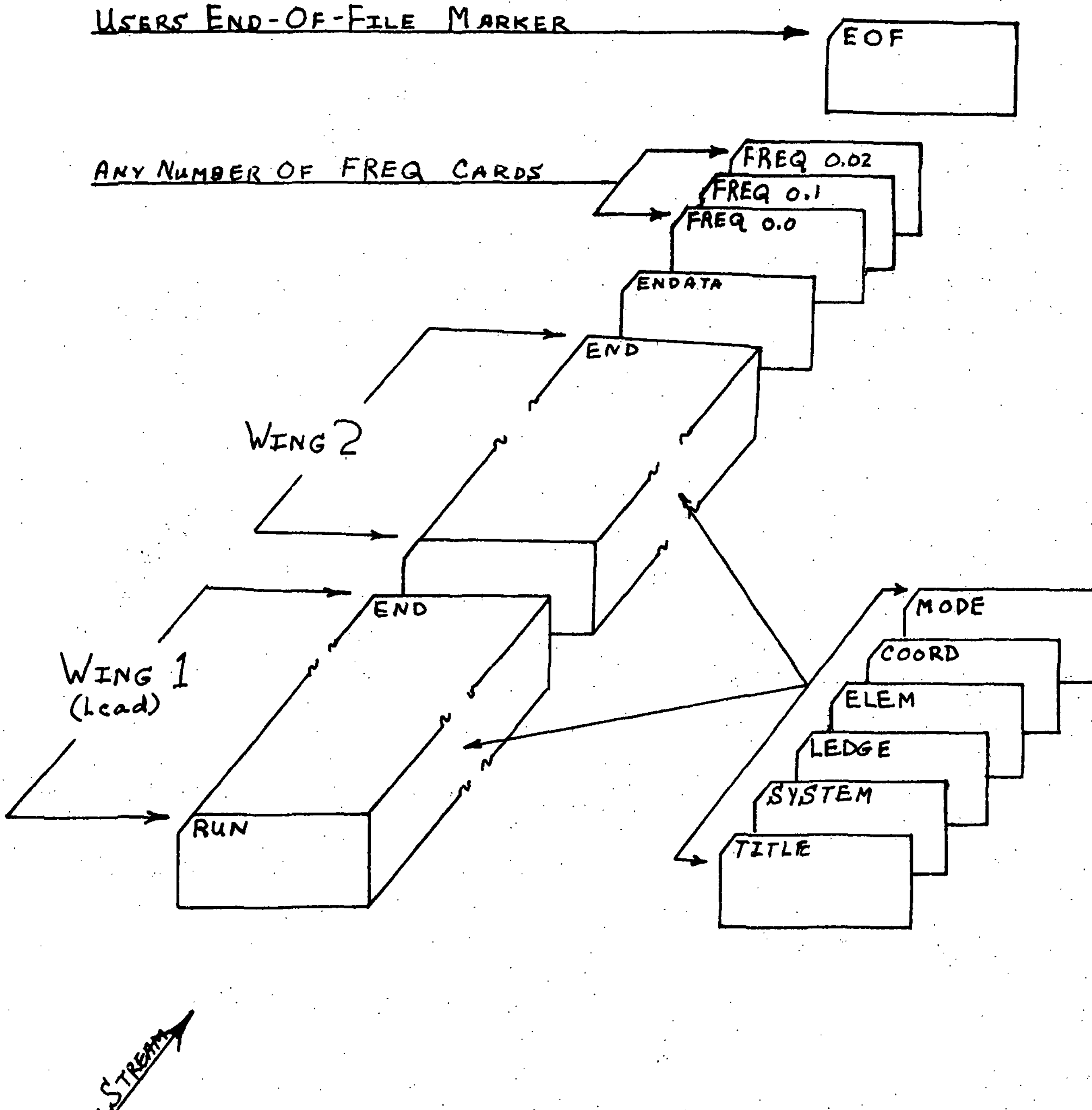


Figure 2.1 Input Overview

Physical arrangement of data deck. Only the LABEL data header cards are shown in their relative locations. Note the absolute position of the FREQ card(s).

Specific data formats correspond to each LABEL section. The formats and the LABEL section using same are presented here.

TYPE	FORMAT (---TYPE---)	LABEL SECTION USING
1	20A4	TITLE
2	A4, A2, I4	Label Cards Only
3	5X, 12I5	SYSTEM (card1); LEDGE
4	A4, 2X, I4, 11I5	ELEM (includes REPEAT)
5	5X, I5, 4E15.6	COORD
6	10X, 4E15.6	MODE, FREQ

SECTION 3

INPUT FORMAT

Input data is necessary for each subsonic/supersonic wing. Therefore, to fully describe the problem, two complete (and independent) sets of data are required. The following pages describe each LABEL data section in detail.

Data is discussed and prepared under the following assumptions:

1. Label data applies to each planform, one at a time (differences noted in the text).

2. Wing 1 is chosen as the leading wing. Wing 2 is normally above Wing 1 (i.e. $Z_2 > 0$) but this is not a requirement.

CARD COLUMN

1	2	3
R	U	N

FORMAT:TYPE 2

This card is optional. It is used to control partial or total execution of the entire program. This card may appear anywhere before the end card.

Case 1. Card Missing

Program will process all data presented. Labeled sections will be accounted for as encountered. Problem size will be computed on the basis of system input data. All input data will be displayed in card image form in the order received.

Execution will terminate after generation of the diaphragm grid point coordinates and element data.

Case 2. Card Present

All of Case 1 procedures plus total execution of the program

CARD COLUMN

1	2	3	4	5	6	7	8	9	10
T	I	T	L	E					N

FORMAT:TYPE 2

This card is optional.

If present, it must be followed by exactly N cards, Type 1 format, containing title information. The information will be displayed exactly as presented, a useful aid in keeping track of output data. Maximum N = 20.

This section may appear anywhere before the END card.

SYSTEM Control Variables Definitions

ITEM 1: Total number of grid points on the wing. This number will be used to input COORD and MODE data.

ITEM 2: Total number of elements on the wing. This number will be used to input ELEM data.

ITEM 3: Total number of degrees of freedom for this system.

ITEM 4: Total number of grid points along the leading edge of the first sub-sonic crank of the wing. (See LEDGE section.)

ITEM 5: Number of equal divisions in the forward mach cone in the diaphragm region. (See Figure 3.1)

ITEM 6: Symmetry factor. Since only the right half of the wing is presented as physical data, the program must be told if the motion of the other half is symmetric (+1) or antisymmetric (-1)

ITEM 7: Extrapolation of leading edge, wing 2 only. For wing 1 leave blank. In situations shown in Figure 3.2, the stagger of the second wing is such that the lead point on the upper wing lies within the forward and rearward mach cones of the lower wing. In this case, the leading edge is extrapolated from the lead point of wing 2 up to the intersection with the rearward mach cone of wing 1. The user must know if such extrapolation is required.

ITEM 8: Wing 1 leave blank. Wing 2 must supply a value (≥ 1) of new points to be entered on the extrapolated portion of the leading edge. If Item 7 is zero or blank, Item 8 may also be neglected.

ITEM 9. Mach number, to be used for both wings (wing 2 value ignored)

ITEM 10. Reference length. All grid point coordinates will be normalized with the wing 1 value.

ITEM 11. Wing 1: This value used for truncation of a partial element near the mach cone during integration. A suggested value is 0.5 percent of the root chord.

Wing 2: This value is used as the stagger distance, measured from lead point of wing 1 to lead point of wing 2. (the distance $\overline{MP}$ in Figure 3.2) The stagger distance is normalized by the reference length before it is used to position the second wing.

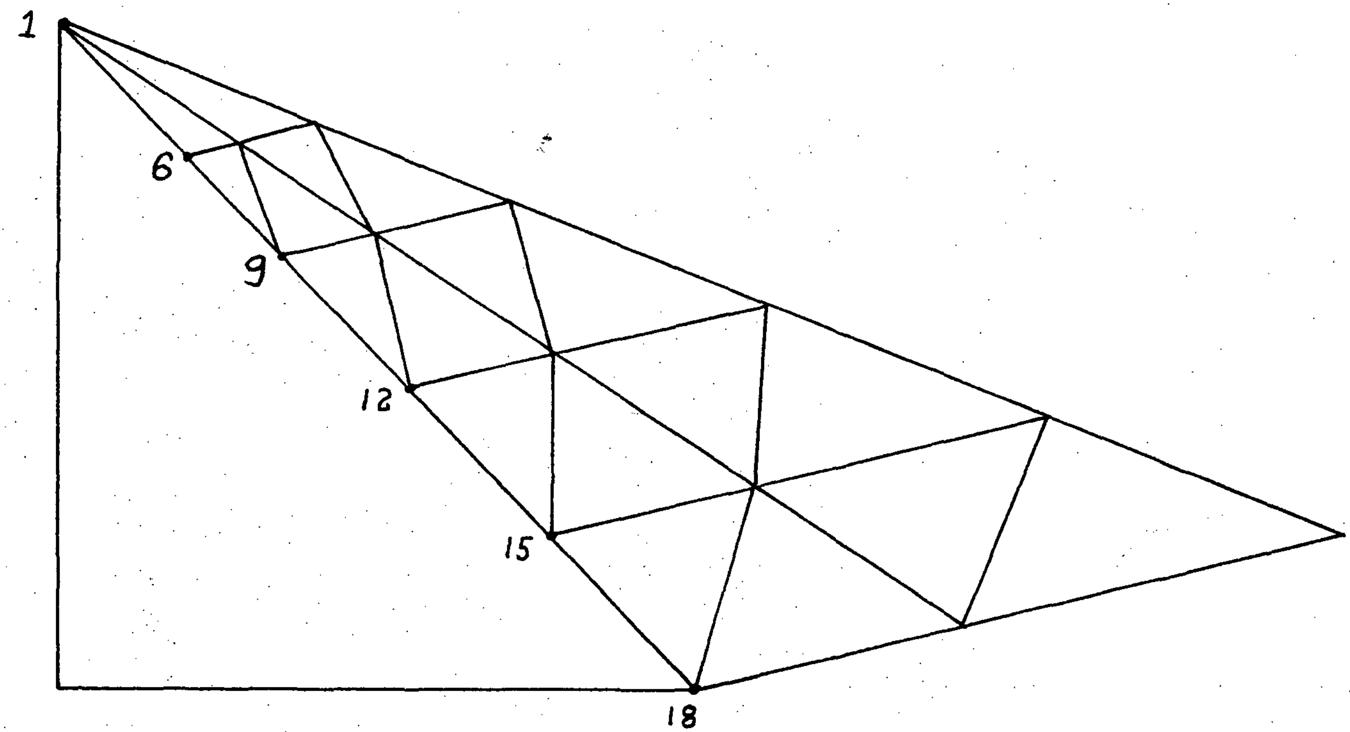


Figure 3.1 DIAPHRAGM ELEMENT GENERATION

Two divisions were requested for this diaphragm. (SYSTEM, Card 1, Item 5=2)

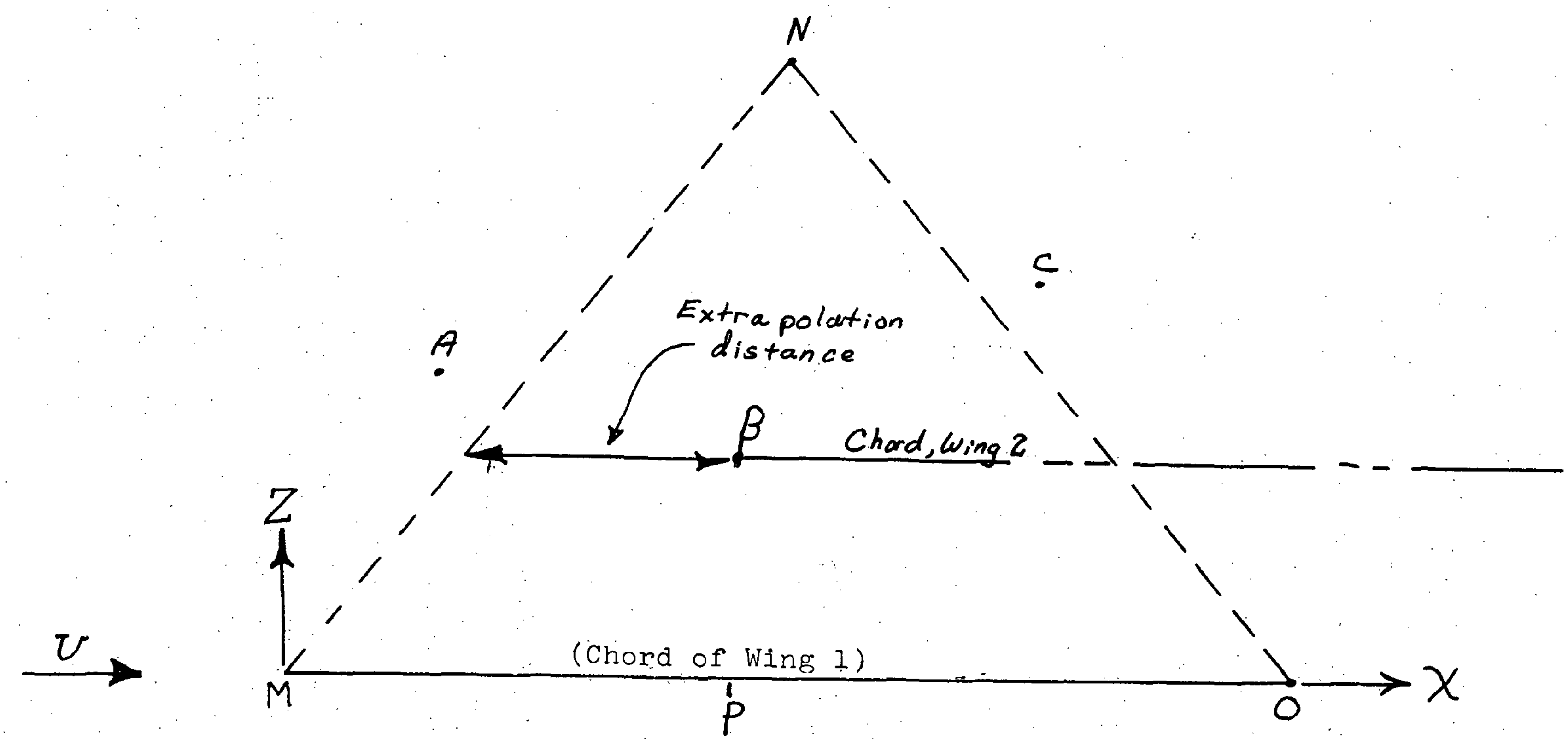


Figure 3.2 Determination of extrapolation for Wing 2.

Answer = yes if lead point of wing 2 lies within the triangular area MNO (as point **B**).

Answer = no if lead point of wing 2 lies outside the triangular area MNO (as points A, C).

CARD COLUMN

1	2	3	4	5	6
S	Y	S	T	E	M

FORMAT:TYPE 2

This card is mandatory.

It may be preceded only by optional cards. The data presented here pertains to the general properties of the system. It must be followed by 2 cards.

Card 1. Format: Type 3

ITEM		CARD COLUMN
1	NBR. of grid points on the wing planform (NP) --------------------	6–10
2	NBR. of elements on the wing ------	11–15
3	NBR. of degrees of freedom -------	16–20
4	NBR. of leading edge grid points --	21–25
5	NBR. of divisions in diaphragm ----	26–30
6	Symmetry -------------------------	31–35
7	Extrapolation --------------------	36–40
8	NBR. of extra grid points on chord for extrapolation -----------------	41–45

Card 2. (System) Format: Type 6

ITEM

9 MACH NBR

11 25

10 Reference Length

41 55

11 Shift (see notes: usage is wing dependent)

56 70

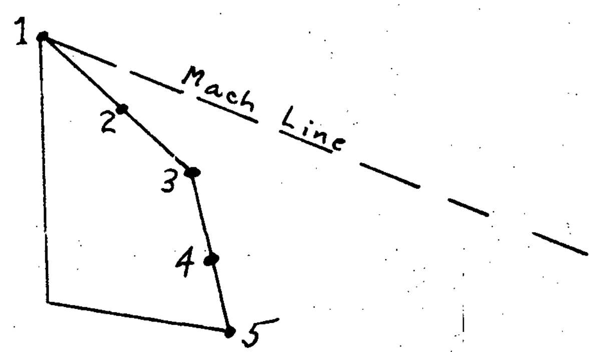
CARD COLUMN

1	2	3	4	5
L	E	D	G	E

FORMAT:TYPE 2

This card is mandatory. It may appear anywhere after SYSTEM section. It must always be present, even for super-sonic leading edges.

The data presented here concerns the leading edge grid point numbers. Start with foremost point on the wing edge that is subsonic. Use 1 or more cards, type 3 format, to describe this data. The example below should clarify the input required.

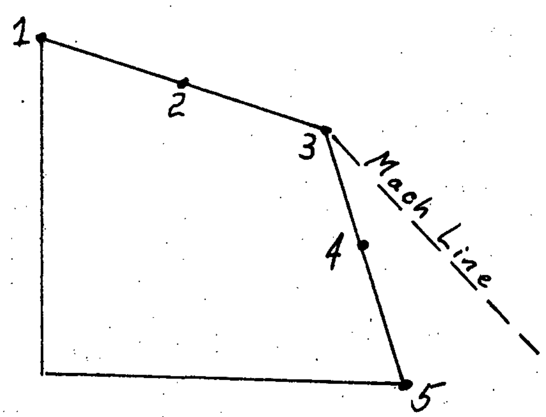


SYSTEM, card 1, item 4 = 5

LEDGE

1	2	3	4	5

Case A. Both cranks sub-sonic.



SYSTEM, card 1, item 4 = 3

LEDGE

3	4	5

Case B. Crank 1 is supersonic, crank 2 is subsonic.
(Since the Mach line drawn at node 1 makes Crank 1 supersonic, it has been shifted to node 3 for clarity.)

CARD COLUMN

1	2	3	4	5
C	O	O	R	D

FORMAT:TYPE 2

This card is mandatory.

It may appear anywhere after SYSTEM. There must follow exactly NP (SYSTEM, card 1, item 1) cards, type 5 FORMAT, containing grid point coordinate data for the planform in questions. Grid point numbers must be generated consecutively, beginning with the number 1 (one).

NOTE: Remember that this data will be divided by reference length supplied on card 2, system.

Field	Card columns
Grid point nbr	6 7 8 9 10
X-coordinate	11–25
Y-coordinate	26–40
Z-coordinate	41–55

CARD COLUMN

1	2	3	4
E	L	E	M

FORMAT:TYPE 2

This card is mandatory.

It may appear anywhere after SYSTEM. The total number of cards to follow must be equal to SYSTEM, card 1, item 3. The cards are type 3 format.

Each card contains 4 numbers as follows:

	Card columns
Element Number	8 9 10
Grid point #1	13 14 15
Grid point #2	18 19 20
Grid point #3	23 24 25

NOTE:

Element numbers must be generated consecutively, beginning with the number 1 (one). Therefore, the total number of elements on the planform (SYSTEM, card 1, item 2) must be equal to the highest element number.

An alternate method of entering element grid point data is available to the user in the form of a REPEAT option. This option can reduce considerably the amount of input data required to define the structure. (Refer to FIGURE 3.3 and Table 3.1)

This technique will be useful only when the grid points of the next higher (numerically) elements (say 1 to N) have their grid point coordinates increased by a common factor. For this case, one need only define a first element and supply a repeat card (type 4 FORMAT) as follows:

CARD COLUMN

1	2	3	4	5	6
R	E	P	E	A	T

Repeat how many times?

8	9	10

Increase grid point #1 by

13	14	15

Increase grid point #2 by

18	19	20

Increase grid point #3 by

23	24	25

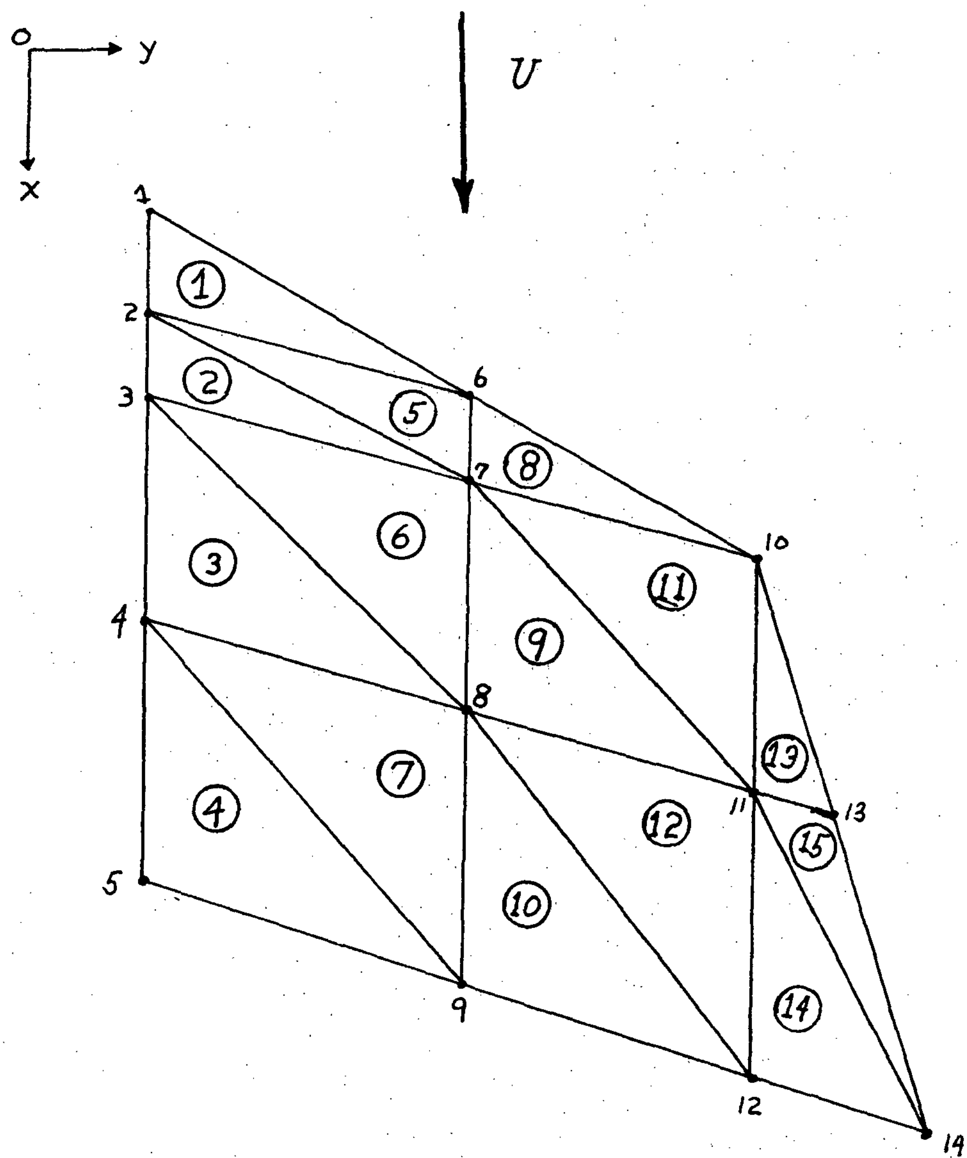


Figure 3.3 Sample Planform of 15 elements and 14 gridpoints. Element numbers are circled.

Full Input

ELEM

1	6	2	1
2	7	3	2
3	8	4	3
4	9	5	4
5	7	6	2
6	8	7	3
7	9	8	4
8	10	7	6
9	11	8	7
10	12	9	8
12	12	11	8
13	13	11	10
14	14	12	11
15	14	13	11
11	11	10	7

Mixed Input

ELEM

	1	6	2	1
REPEAT	3	1	1	1
	5	7	6	2
REPEAT	2	1	1	1
	8	10	7	6
REPEAT	2	1	1	1
	11	11	10	7
	12	12	11	8
	13	13	11	10
	14	14	12	11
	15	14	13	11

Table 3.1 ELEMent grid points Data for the Sample structure in Figure 3.3

1	2	3	4
M	O	D	E

FORMAT:TYPE 2

This card is mandatory. It may appear anywhere after system.

Data presented here refers to the mode shapes applicable to this test/planform. The data is considered an array, card position implies grid point number, and column position the relative mode shape. Therefore, there must be NP (SYSTEM, card 1, item 1) cards of type 6 format.

Note:

Mode shape data is used as received. No normalization process occurs. Therefore, the user must be careful to insert the correct mode shape data.

CARD COLUMN

1	2	3
E	N	D

FORMAT:TYPE 2

This card is mandatory.

It must physically appear as the last card of a wing (planform) description.

CARD COLUMN

1	2	3	4	5	6
E	N	D	A	T	A

FORMAT:TYPE 2

This card is mandatory.

It must appear immediately after the second END card, i.e. at the end of the label data describing wing 2. If this card is missing, execution is terminated before any data is processed. (I.E. The program strikes an END-OF-FILE condition, and reacts accordingly).

CARD COLUMN

1	2	3	4		11 — 25
F	R	E	Q	. . .	κ

This card is mandatory.

The numerical value (κ) placed on this card is called the "reduced frequency" and is determined by

$$\kappa = \frac{\omega L}{v}$$

where ω = angular flow frequency
L = reference length (SYSTEM, item 10)
v = flight speed.

Although κ is normally considered to be complex, the real part is taken as zero and the user enters only the magnitude of the complex part as a floating point number in columns 11 thru 25. To compute generalized forces for more than one frequency, simply enter additional cards. Each card contains only one frequency. No limit as to the number of cards allowed.

Place all frequency cards immediately after "ENDATA" label card.

SECTION 4

SAMPLE PROBLEM/DATA/RESULTS

The purpose of this section is to demonstrate graphically how the user describes a planform, the actual data required, and the results generated by the computer. Figure 4.1 shows a simple DELTA-WING planform consisting of 4-gridpoints and 2-elements. The broken line elements and gridpoints are generated interally, but the user should always have an idea of what this "DIAPHRAGM" region looks like before data preparation begins. The angle θ ($\angle$ 2,1,6) is computed thru SINE θ = 1 / (MACH NBR). Gridpoints are indicated by numbers. Elements are the circled numbers. Note that the coordinate system is a normal right-handed system if this page is turned 90-degrees. The CHORD of this planform lies on the X-axis, with gridpoint 1 at the origin.

Should questions arise during the study of this example, re-read the LABEL section covering the question.

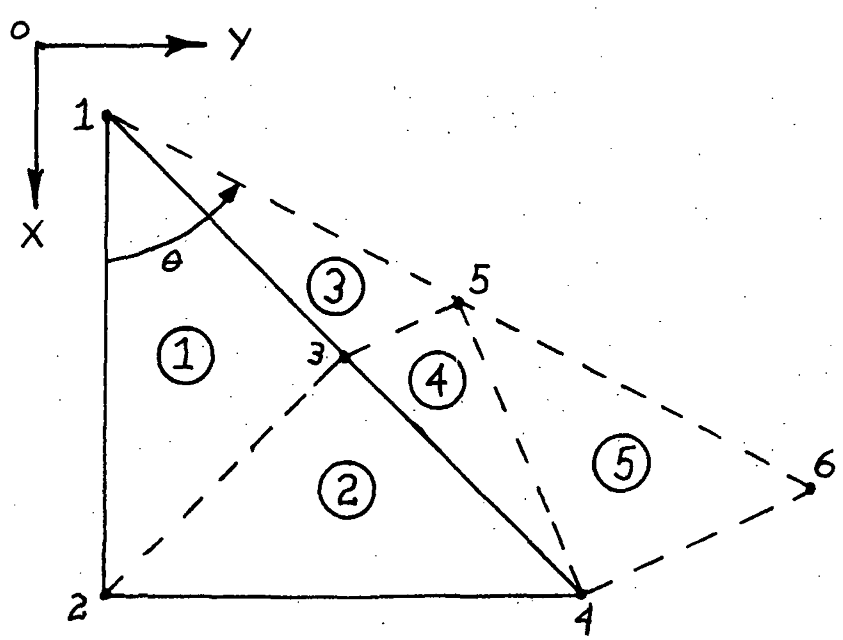


Figure 4.1 Sample Planform Showing Basic Structure and Program Generated Elements

The printout from any run will have the same form as that presented here. (Note: this printout has been compressed to preserve continuity. The content remains unchanged.) Under conditions of supersonic wings, no diaphragm is generated and therefore no printout occurs for that section of the run. The following discussion will serve as a guide to understanding all results.

ITEM	DESCRIPTION	PAGES
A.	An echo-check of the entire data deck	33
B.	Process data, display after assignment to internal variables. Successful input processing yields a +++END CARD ENCOUNTERED+++	34-37
C.	Generation of diaphragm	38-39
D.	Display input downwash	40
E.	Formal output begins at TITLE	41
F.	Wing 1, potentials, pressures, generalized forces	42
G.	Wing 2, potentials, pressures, generalized forces	43
H.	Repeat D thru G for each additional frequency	-
I.	Job completed. Message END OF JOB	44

Abnormal termination of the program is defined by a) a full page message ERROR HALT, b) sufficient messages to indicate the reason, c) under certain conditions a core dump will be provided. Poor input data will normally be the problem.

The problem results (items F, G above are formally defined as follows:

1. Velocity potentials $\tilde{\Phi}$

$$\phi = - \qquad \tilde{\Phi}$$

2. Pressure (in terms of nodal forces) $\tilde{P}$

$$P = -4 q_0 L^2 \tilde{P}$$

3. Generalized forces $\tilde{Q}_{ij}$ (complete wing)

$$Q_{ij} = -8 q_0 L^3 \tilde{Q}_{ij}$$

where $q_0 = \frac{1}{2} \rho V^2$ is the dynamic pressure

This completes the description of the computer printout.

A I C / I N T......D A T A D E C K

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
RUN                                                                     TEST0001
TITLE    9                                                              TEST0002
                                                                        TEST0003
           .. A I C   /   I N T ..     .. T E S T   C A S E ..          TEST0004
         THIS  EXAMPLE  IS  USED  TO  DEMONSTRATE  THE  INPUT  DATA      TEST0005
         REQUIRED  TO  EXECUTE  THE  'AIC / INT'  PROGRAM.              TEST0006
         BOTH  WINGS  ARE  IDENTICAL,  AND  THE  UPPER  WING  LIES       TEST0007
         DIRECTLY  ABOVE  THE  LOWER  WING (I.E.  STAGGER  DISTANCE      TEST0008
         IS  ZERO).  BOTH  WINGS  ARE  SUB-SONIC.  EXECUTION  TIME       TEST0009
         IS  TRIVIAL.  FULL  LOGIC  IS  EMPLOYED  DURING  ANALYSIS.      TEST0010
                                                                        TEST0011
SYSTEM                                                                  TEST0012
         4    2    2    3    1    1                                     TEST0013
              1.15                          2.0            .005         TEST0014
LEDGE                                                                   TEST0015
         1    3    4                                                    TEST0016
ELEM                                                                    TEST0017
         1    1    2    3                                               TEST0018
         2    2    4    3                                               TEST0019
COORD                                                                   TEST0020
         1    0.0            0.0                                        TEST0021
         2    2.0            0.0                                        TEST0022
         3    1.0            1.0                                        TEST0023
         4    2.0            2.0                                        TEST0024
MODE                                                                    TEST0025
         1    1.0           -1.0                                        TEST0026
         2    1.0            1.0                                        TEST0027
         3    1.0            C.0                                        TEST0028
         4    1.0            1.0                                        TEST0029
END                                                                     TEST0030
TITLE    5                                                              TEST0031
                             * * * N O T E * * *                        TEST0032
         THESE  CARDS  ARE  BEING  PRINTED  FROM  'WING - 2'            TEST0033
         DATA.    THEREFORE  USER  MAY  KEEP  DATA  LABELED             TEST0034
         WITH  A  TITLE  SECTION  AND  IT  WILL  NOT  INTEFER           TEST0035
         WITH  PROGRAM  INPUT.                                          TEST0036
SYSTEM                                                                  TEST0037
         4    2    2    3    1    1                                     TEST0038
              1.15                          2.0            0.00         TEST0039
LEDGE                                                                   TEST0040
         1    3    4                                                    TEST0041
ELEM                                                                    TEST0042
         1    1    2    3                                               TEST0043
         2    2    3    4                                               TEST0044
COORD                                                                   TEST0045
         1    0.0            0.0            0.5                         TEST0046
         2    2.0            0.0            0.5                         TEST0047
         3    1.0            1.0            0.5                         TEST0048
         4    2.0            2.0            0.5                         TEST0049
MODE                                                                    TEST0050
         1    1.0           -1.0                                        TEST0051
         2    1.0            1.0                                        TEST0052
         3    1.0            C.0                                        TEST0053
         4    1.0            1.0                                        TEST0054
END                                                                     TEST0055
ENDATA                                                                  TEST0056
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

```
...W I N G..1.....C O N T R L S...

NBR  GRID  POINTS  ON  WING...     4
NBR  ELEMENTS ON  PLANFORM....     2
NBR  DEGREES  OF  FREEDOM.....     2
NBR  LEADING  EDGE  POINTS....     3
NBR  DIVISIONS  IN  DIAPHRAGM.     1
SYMMETRY  FACTOR.............      1
REFERENCE  LENGTH..... 0.2000OE C1


..G E N E R A L....C O N T R L S..

M A C H  NUMBER....... 0.115C0E C1
NBR  MODE  SHAPES............     2
TRUNCATION  (EPS)..... 0.5C0C0E-C2


LEADING  EDGE  GRID  POINTS.
1    3    4
```

ELEMENT GRID POINTS

ELEM	A	B	C
1	1	2	3
2	2	4	3

GRID POINT COORDINATES

GRID POINT	X	Y	Z
1	0.0	0.0	0.0
2	0.100000E 01	0.0	0.0
3	0.5000CCE 00	0.500000E 00	0.0
4	0.100000E 01	C.100000E 01	0.0

MODE SHAPE DATA

1	0.100000E 01	-0.1C0000E 01
2	0.100000E 01	0.1C0C0E 01
3	0.100000E 01	0.0
4	0.100000E 01	0.1C0000E 01

```
...W I N G..2.....C O N T R L S...

NBR  GRID  POINTS  ON  WING...    4
NBR  ELEMENTS ON  PLANFORM....    2
NBR  DEGREES  OF  FREEDOM.....    2
NBR  LEADING  EDGE  POINTS....    3
NBR  DIVISIONS  IN  DIAPHRAGM.    1
SYMMETRY   FACTOR.............    1
REFERENCE  LENGTH..... 0.20000E 01


..G E N E R A L....C O N T R L S..

EXTRAPOLATION REQUIRED(1=YES).    C
STAGGER      (LE.TO.LE) 0.0


LEADING  EDGE  GRID  POINTS.
1    3    4
```

ELEMENT GRID POINTS

ELEM	A	B	C
1	1	2	3
2	2	3	4

GRID POINT COORDINATES

GRID POINT	X	Y	Z
1	0.0	C.0	0.250000E 00
2	0.10000CE 01	0.0	0.250000E 00
3	0.5000CCE 00	0.5000C0E 00	0.250000E 00
4	0.100000E 01	C.100000E 01	0.250000E 00

MODE SHAPE DATA

1	0.100000E 01	-0.1CC000E 01
2	0.100000E 01	0.1C0000E 01
3	0.100000E 01	0.0
4	0.100000E 01	0.1C0000E 01

+++++ END CARD ENCCUNTERED +++++

W I N G.....O N E

DIAPHRAGM ELEMENTS WERE
ADDED AS FOLLOWS.

GRID POINT COORDINATES

GRID POINT	X	Y	Z
5	0.391973E 00	C.690226E 00	0.0
6	0.783945E 00	0.138045E 01	0.0

ELEMENT GRID POINTS

ELEM	A	B	C
3	3	5	1
4	4	5	3
5	4	6	5

2 MACH LINE GRID PCINTS.

5 6

W I N G....T W O

DIAPHRAGM ELEMENTS WERE
ADDED AS FOLLOWS.

GRID POINT COORDINATES

GRID POINT	X	Y	Z
5	0.391973E 00	0.690226E 00	0.250000E 00
6	0.783945E 00	0.138045E 01	0.250000E 00

ELEMENT GRID POINTS

ELEM	A	B	C
3	3	5	1
4	4	5	3
5	4	6	5

2 MACH LINE GRID POINTS.

5 6

INPUT......DOWNWASH

ROW	COL 1 REAL	COL 1 IMAG	COL 2 REAL	COL 2 IMAG
1	0.0	0.4000CCE 00	C.2C000CE 01	-0.400000E 00
2	0.0	0.4000C0E 00	C.2C00CCE 01	0.400000E 00
3	0.0	0.4000CCE 00	0.2C0000E 01	0.0
4	0.0	0.4000CCE 00	0.2C000CE 01	0.400000E 00
5	0.0	0.400000E 00	C.2C0000E 01	-0.400000E 00
6	0.0	0.400000E 00	0.200000E 01	0.400000E 00
7	0.0	0.40000CE 00	0.2C0000E 01	0.0
8	0.0	0.400000E 00	0.200000E 01	0.400000E 00

```
                    * * * * * * * * * * *
                    *                   *
                    *   T  I  T  L  E   *
                    *                   *
                    * * * * * * * * * * *

                                                                   TEST0003
  .. A I C   /   I N T ..     .. T E S T   C A S E ..              TESTOCC4
THIS EXAMPLE IS USED TO DEMONSTRATE THE INPUT DATA                 TEST0005
RECUIRED TO EXECUTE THE 'AIC / INT' PROGRAM.                       TEST0006
BOTH WINGS ARE IDENTICAL, AND THE UPPER WING LIES                  TEST0007
DIRECTLY ABOVE THE LOWER WING (I.E. STAGGER DISTANCE               TEST0008
IS ZERO). BOTH WINGS ARE SUB-SONIC. EXECUTION TIME                 TEST0009
IS TRIVIAL. FULL LOGIC IS EMPLOYED DURING ANALYSIS.                TEST0010
                                                                   TEST0011
                 * * * N O T E * * *                               TEST0032
THESE CARDS ARE BEING PRINTED FROM 'WING - 2'                      TEST0033
DATA.    THEREFORE USER MAY KEEP DATA LABELED                      TEST0034
WITH A TITLE SECTION AND IT WILL NOT INTEFER                       TEST0035
WITH PROGRAM INPUT.                                                TEST0036
```

...W I N G....U N E...

MACH NBR.. 0.1150E 01
FREQUENCY.. 0.4000E 00

V E L O C I T Y ...... P O T E N T I A L S

ROW	COL 1 REAL	COL 1 IMAG	COL 2 REAL	COL 2 IMAG
1	0.0	0.0	0.0	0.0
2	0.271526E 00	0.506305E 00	0.268412E 01	-0.108701E 01
3	0.393869E-01	0.101497E 00	0.491935E 00	-0.234013E 00
4	0.184515E 00	0.249123E 00	0.126373E 01	-0.838053E 00

R E S U L T A N T ...... P R E S S U R E S

ROW	COL 1 REAL	COL 1 IMAG	COL 2 REAL	COL 2 IMAG
1	0.175622E-01	0.447830E-01	0.234685E 00	-0.641168E-01
2	0.334217E-01	0.994732E-01	0.517793E 00	-0.103803E 00
3	0.401685E-01	0.956043E-01	0.503576E 00	-0.140339E 00
4	0.222219E-01	0.517025E-01	0.271975E 00	-0.738901E-01

G E N E R A L I Z E D .... F O R C E S

ROW	COL 1 REAL	COL 1 IMAG	COL 2 REAL	COL 2 IMAG
1	0.113374E 00	0.291563E 00	0.152803E 01	-0.382149E 00
2	0.380814E-01	0.106393E 00	0.555082E 00	-0.113576E 00

...W I N G....T W O...

MACH NBR.. 0.1150E 01
FREQUENCY.. 0.4000E 00

V E L O C I T Y ...... P O T E N T I A L S

ROW	COL 1 REAL	COL 1 IMAG	COL 2 REAL	COL 2 IMAG
1	0.0	0.0	0.0	0.0
2	0.271527E 00	0.506306E 00	0.268412E 01	-0.108701E 01
3	0.393868E-01	0.101497E 00	0.491935E 00	-0.234013E 00
4	0.184515E 00	0.249124E 00	0.126373E 01	-0.838053E 00

R E S U L T A N T ...... P R E S S U R E S

ROW	COL 1 REAL	COL 1 IMAG	COL 2 REAL	COL 2 IMAG
1	0.175622E-01	0.447831E-01	0.234685E 00	-0.641168E-01
2	0.334217E-01	0.994732E-01	0.517793E 00	-0.103803E 00
3	0.401695E-01	0.956043E-01	0.503577E 00	-0.140339E 00
4	0.222219E-01	0.517025E-01	0.271975E 00	-0.738900E-01

G E N E R A L I Z E D .... F O R C E S

ROW	COL 1 REAL	COL 1 IMAG	COL 2 REAL	COL 2 IMAG
1	0.113374E 00	0.291563E 00	0.152803E 01	-0.382149E 00
2	0.380814E-01	0.106393E 00	0.555083E 00	-0.113576E 00

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

EEEEEEE   N     N   DDDDDD
E         NN    N   D     D
EEEE      N N   N   D     D
E         N  N  N   D     D
E         N   N N   D     D
EEEEEEE   N     N   DDDDDD

        OOOOO    FFFFFFF
       O     O   F
       O     O   FFFF
       O     O   F
       O     O   F
        OOOOO    F

       J    OOOOO    BBBBBB
       J   O     O   B     B
       J   O     O   BBBBBB
       J   O     O   B     B
J      J   O     O   B     B
 JJJJJ      OOOOO    BBBBBB

++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

SECTION 5

RESTART / PUNCHED OUTPUT

The AIC/INT program has an additional analytic feature called "RESTART". What the word restart really means is that the user may alter MODE shape data and generate new aerodynamic coefficients without making all of the initial calculations performed on the initial run. An assumption is made that the data from the initial run was permanently stored.

Punched output (generalized forces and pressures) is also an option. Each block of data punched contains a descriptive lead card containing the type (forces or pressures), wing number and mach number.

To exercise either of the above options, code in columns 9 and 10 of the run card as follows:

+1 = punch generalized forces

+2 = punch generalized forces and pressures

-1 = punch generalized forces and restart

-2 = punch generalized forces, pressures and restart

The format of the punched output is (4E15.6).

SECTION 6

HINTS ON USING AIC/INT

The following comments apply to every planform the user wishes to test.

a. Create a scale drawing of the planform.

b. Create finite element pattern by
   1. selecting gridpoints first and draw connecting lines;

      or

   2. draw lines first and let intersections be gridpoints.

c. Label grid points in increasing order, from 0 to +x, 0 to +y.

d. Label elements as in c. above, numbering all elements in increasing order starting with 1 (one).

e. Prepare ELEM data by choosing gridpoint #1 to have the <u>largest</u> x value of the 3 points involved. (Any method is acceptable.)

f. Prepare COORD data.

g. Prepare remainder of data.

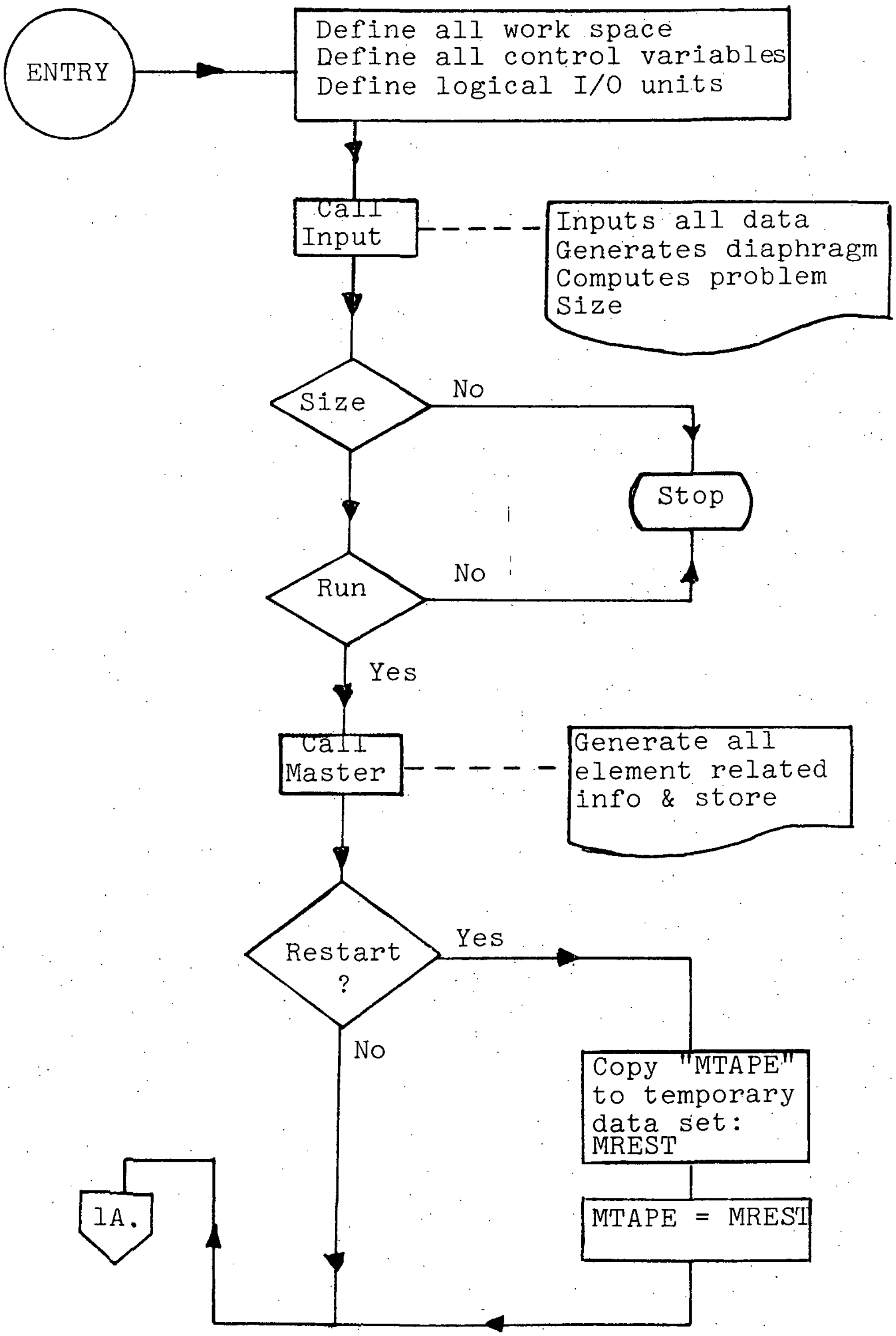
h. Submit data to execution but leave out <u>RUN</u> card.

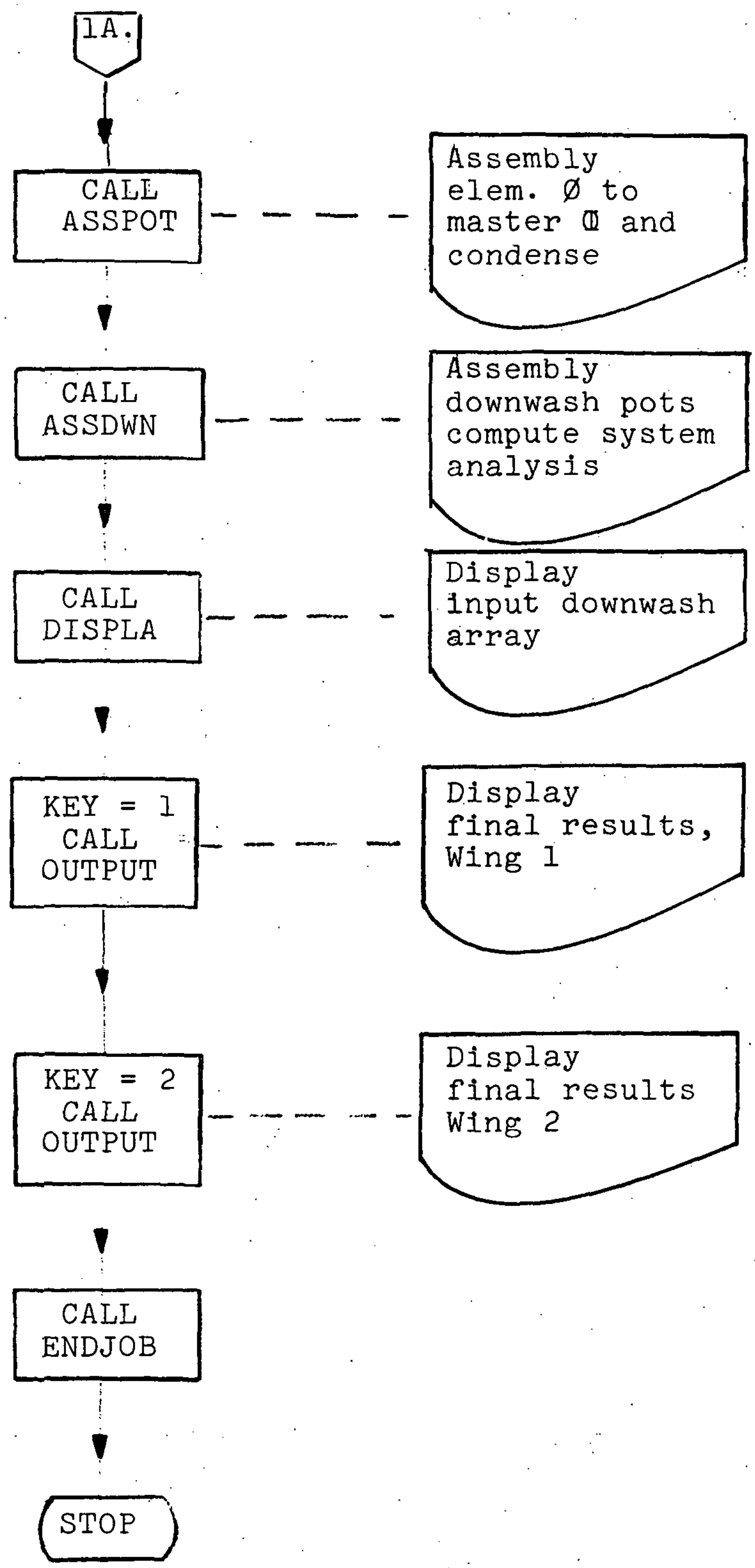
i. Check the printout of the input data <u>carefully</u> for errors. Compare the grid point data with the scale drawing of item a.

j. Prepare frequency cards, enter after ENDATA card, include a RUN card and begin execution.

SECTION 7

COMPUTER PROGRAM FLOW




1A.
CALL ASSPOT
Assembly elem. Ø to master Ⓜ and condense
CALL ASSDWN
Assembly downwash pots compute system analysis
CALL DISPLA
Display input downwash array
KEY = 1 CALL OUTPUT
Display final results, Wing 1
KEY = 2 CALL OUTPUT
Display final results Wing 2
CALL ENDJOB
STOP

SECTION 8

SIZE LIMITATIONS

At delivery date this program contains the following limitations (applicable to planform):

1. Nbr. gridpoints on wing $\leq$ 40
2. Nbr. gridpoints on diaphragm $\leq$ 15
3. Nbr. degrees of freedom $\leq$ 10
4. Nbr. leading edge gridpoints $\leq$ 20
5. Nbr. elements (wing + diaphragm) $\leq$ 100
6. Nbr. title cards $\leq$ 20

These limitations are subject to change.

REFERENCES

1. Appa, K. and Smith, G. C. C., "Development and Applications of Supersonic Unsteady Consistent Aerodynamics for Interfering Parallel Wings", NASA CR-2168

2. Paine, A. A., "Development and Applications of Supersonic Unsteady Consistent Aerodynamics for Interfering Parallel Wings,- Programmers Manual", NASA CR-112185